Performance of Three Wheat Seeders in Conservation Tillage Residue

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ABSTRACT

GROWERS have experienced difficulty with wheat seeders plugging in conservation tillage residue. Three types of seeders were evaluated for planting wheat in varying amounts of residue on the Southern Great Plains. The seeders, a no-till double-disk opener drill, a hoe-press drill, and a blade-air seeder, were compared for residue handling, soil penetration, seed placement, and seedling emergence under no-till, sweep tillage, and disk tillage conditions.

All seeders operated successfully through 3,500 kg/ha (3,100 lb/acre) of stubble. The hoe-press drill produced significantly greater seedling emergence on most treatments because the narrow seed trench and weighted press wheels caused favorable seed-soil contact. The blade-air seeder had a minimum effective seeding depth of 6 cm (2.35 in.), which was nearly twice the depth of the other drills. Because of soil fluffing from the lifting action of the blade, weighted press wheels were required to firm the seed zone. Methods of prior tillage did not significantly affect emergence. The hoe-press drill provided the best stand establishment under the conditions tested.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is well adapted and widely grown throughout the Great Plains. Wheat was among the first crops, historically, to be managed with reduced tillage in the form of "stubble-mulch" (Allen and Fenster, 1986). In recent years, the availability of improved tillage equipment and herbicides for weed and volunteer wheat control has enhanced the acceptance of minimum tillage and no-till concepts known as "conservation tillage". Farmers such as Vance Ehmke (1980) of western Kansas have complained that many grain drills could not seed through heavy stubble without plugging. This is especially a concern when the next crop of winter wheat is seeded within 3 to 4 months of the previous harvest, which results in little time for residue deterioration.

An important factor when considering the capacity of seeders to pass through various amounts of residue is the orientation of stubble and the moisture content (Allen et al., 1984). For example, 3,500 kg/ha (3,100 lb/acre) of above-ground dry matter in the form of standing stubble can easily increase to about 5,000 kg/ha (4,450 lb/acre) after sweep-tilling when root clumps are exposed. For this reason, a treader attached to the rear of a sweep-tiller can help break long lengths of straw and lessen problems of seeder plugging.

One recent approach, introduced first in Canada and then in the U.S., has been the introduction of pneumatic (air) seed delivery systems to distribute seed behind field cultivators or chisel plows (Allen and Fenster, 1986). Distribution tubes release seed behind the cultivator shanks. These units can operate through large amounts of residue. One shortcoming of this type of air seeder is uneven depth of seed placement. Mark Schrock (1982) of Kansas State University has suggested use of individual parallel linkage and press wheels for each opener to improve control of seeding depth. Other Kansas State University agricultural engineers introduced prototypes for air seeding row crops such as sorghum by injecting seed directly behind 1.5-m (5-ft) V-blades into wheat stubble (Herron, 1978; Suderman and Clark, 1981). The Flex-King Corporation* acquired production rights to the KSU planter system and introduced a seed distribution manifold, attached directly behind the V-blade, for seeding small grains in 25-cm (10-in.) spaced rows.

Other investigators have evaluated and modified disk and hoe opener grain drills for stand establishment and grain production, mostly in the Northern Great Plains and in the Palouse wheat growing area of the northwestern U.S. (Klocke, 1979; Krall et al., 1978; Payton et al., 1985; Townsend and Chinsuwan, 1976; Wilkins et al., 1983). The hoe drill has been used in the Great Plains for more than 50 years and has been upgraded and is well adapted to stubble-mulch culture. The weight on the rear of the hoe drill is carried on the press wheels.

Hoe openers can penetrate deeper (7 to 13 cm) (3 to 5 in.) than double-disk openers (4 to 7 cm) (1.5 to 3.0 in.) when necessary to reach moist soil without leaving excessive soil cover over the seed (Allen et al., 1984). For example, the hoe-press drill can place seed about 10 cm (4 in.) below the field surface and leave only 4 cm (1.5 in.) of firmed seed cover in the press wheel depression

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*The mention of a manufacturer, trade name, or proprietary product is for information only and does not imply endorsement by USDA to the exclusion of another product which may be suitable, nor does it imply registration under FIFRA as amended.

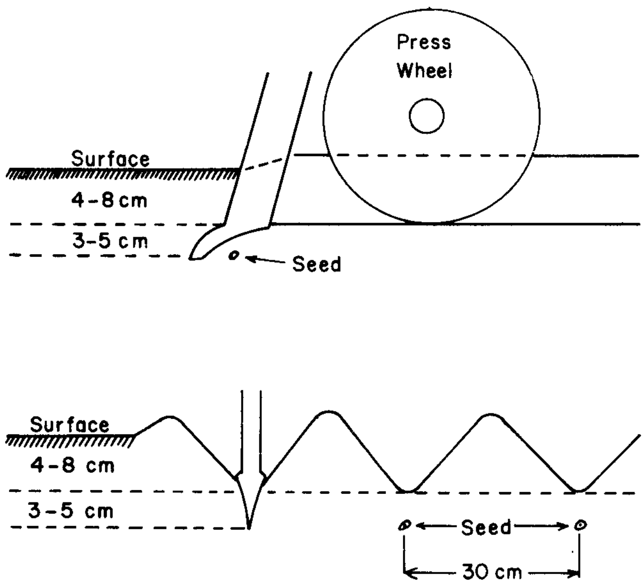


Fig. 1—Side view and front view, hoe-press drill seed opener showing seed furrow and seed placement configuration. (Redrawn from Pumphrey, 1975).

(Pumphrey et al., 1975) (Fig. 1). To accomplish this, dry surface soil is pushed aside—forming ridges between seed rows. Relatively wide 25- to 45-cm (10- to 18-in.) seed row spacing also improves residue clearance, especially when openers are offset in two ranks (Fig. 3). Narrower 18-cm (7-in.) seed row spacing can be achieved when openers are offset in three ranks to maintain lateral clearance.

Norman Klocke (1979) of the University of Nebraska developed a prototype hoe drill with coulters to no-till seed through small grain stubble. The coulter increased the capacity of the drill to operate through stubble. Since then, industry has begun to introduce commercial model hoe-press drills with coulters. Double-disk opener no-tills drills have proliferated during the past 10 years. They feature optional front-mounted residue and soil cutting coulters and rear press wheels for seed-row closure and seed-to-soil pressing. Opener spacings of 18 to 25 cm (7 to 10 in.) generally are available.

This study was initiated to investigate the performance of three different types of seeders in no-till, sweep-till, and disk-till conditions on hardland soils in the Southwestern Great Plains wheat area. The study compared the new blade-air seeder concept (KSU-Flex-King design) with the hoe-press (hoe) and no-till double-disk opener (disk) drills. The objectives were to evaluate the three distinctly different types of wheat seeders for soil penetration, residue clearance, seed placement and covering, and stand establishment under differing residue conditions.

PROCEDURE

The study was conducted at the USDA-ARS Conservation and Production Research Laboratory at Bushland, TX, on a continuous wheat production system during 1984 and 1985. Timely precipitation, 16% above average, in both years assured adequate fall and spring growth without requiring sprinkler irrigation.

The experiment had a randomized design of three tillage treatments as main plots 25 x 100 m (81 x 320 ft) and three seeder treatments as 8- x 100-m (27- x 320-ft) subplots and two replications. The tillage treatments were as follows:

Disk Tillage (residue incorporated)—Plots were tandem disked 2 to 3 times between late June harvest and late September to October seeding to control weeds and volunteer wheat and to mix residue into the soil.

Sweep Tillage—A flex-frame undercutting sweep tiller having 1.5-m (5-ft) V-blades was used after harvest and as needed to control weeds and volunteer wheat. An attached stubble treader was used on the last operation before seeding to improve control of volunteer wheat. Two to three sweep operations were required.

No-Till—2, 4-D [(2, 4-dichlorophenoxy) acetic acid] was applied immediately after harvest for broadleaf weed control; and paraquat [1,1′-dimethyl-4,4′-bipiridinium salts] or glyphosate [N-(phosphonomethyl) glycine] were applied as needed to control volunteer wheat, usually requiring two applications.

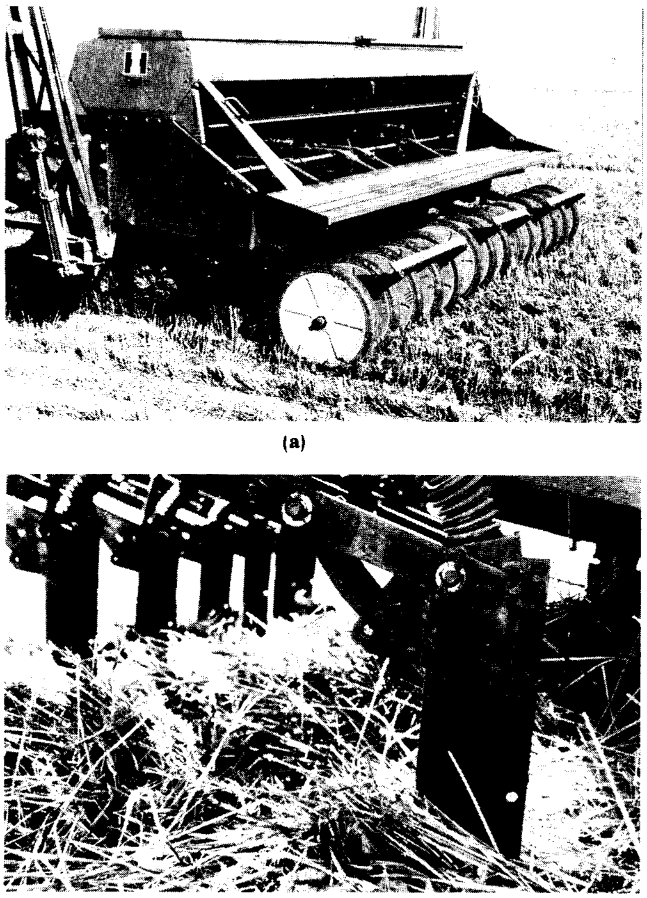
The soil, a fine-textured Pullman (Torrertic Paleustoll) clay loam described by Unger and Pringle (1981) is commonly referred to as a "hardland" and is regarded as a high-draft soil. It has a silty clay loam Ap horizon 0 to 15 cm (0 to 6 in.) deep that is underlain by a dense clay B21t horizon 15 to 40 cm (6 to 16 in.) deep.

A description of the three wheat seeders that were evaluated follows. The machine weight and downforce values for each seed opener, as discussed herein, are with seed boxes empty.

Disk Drill—The unit was a 4.1-m (14-ft) wide Graham Hoeme no-till drill having rippled coulters, 25-cm (10-in.) spaced 34-cm (13.5 in.) diameter double-disk openers, and two angle mounted 5- x 32-cm (2- x 13-in.) rubber tired plastic press wheels which straddled the seed row (Fig. 2). Seed metering was through fluted feed cups. The unit weighed 2,500 kg (5,500 lb), or 156 kg (343 lb) per coulter-opener assembly. Up to 40 kg (90 lb) downforce could be applied to each opener.

Hoe Drill—The unit was an International 7100 press drill, having about one-half of the weight carried on the rear press wheels (Fig. 3). The unit was 4.2 m (14 ft) wide, having 14 30-cm (12-in.) spaced narrow hoe point openers. The openers were offset in two 71-cm (27-in.)

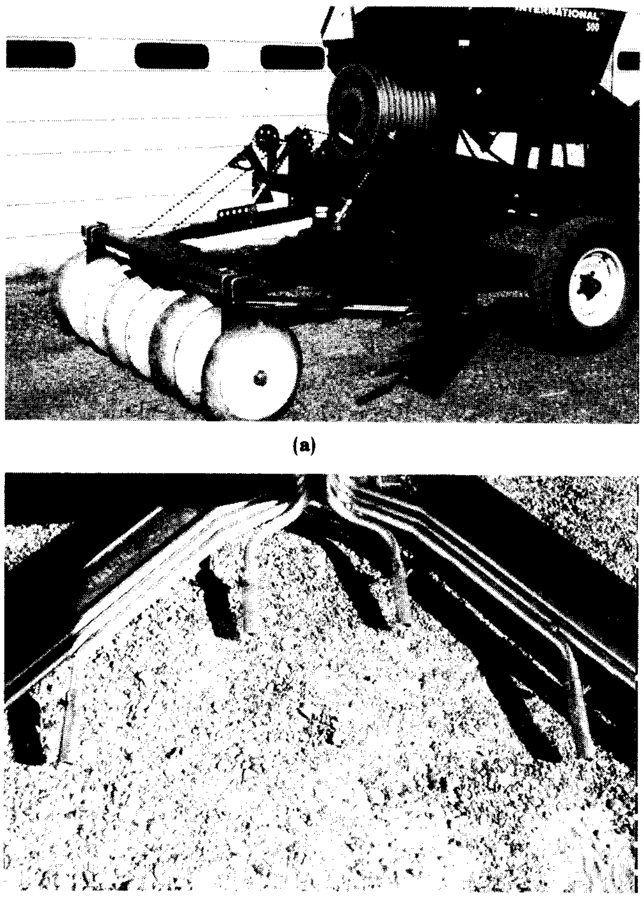
Fig. 2—No-till drill with ripple coulter, double-disk opener, and double-angled press wheels.



(a)

(b)

Fig. 3—(a) Hoe-press drill with rear weight carried on press wheels. (b) Hoe opener-seed boot operating in dry wheat residue.



(a)

(b)

Fig. 4—(a) Blade-air plot seeder showing seed manifold and press wheels. (b) Close-up of seed distribution manifold attached to blade.

spaced ranks so that adjacent openers were 61 cm (24 in.) apart for residue clearance. Seed metering was through fluted-roll cups. The unit weighed 1,630 kg (3,600 lb). Up to 80 kg (180 lb) downforce could be applied to each opener.

Blade-Air Seeder—A plot size unit* was fabricated by modifying and adapting components of commercial equipment (Fig. 4). An International Cyclo 500 air seed metering unit was mounted on a two-wheeled Noble Blade carrier frame that had one 2.13-m (84-in.) wide 75-deg angle V-blade. A stainless steel seed distribution manifold was attached to the rear of the blade, placing seed in 8 25-cm (10-in.) spaced rows (Fig. 4b). Tubes on the blade manifold were connected to the Cyclo metering manifold with flexible hoses. Trailing V-edged steel press wheels were spring loaded for added down pressure. The blade seed distribution manifold was manufactured by Pickle Creek Mfg. Co.*, and the press wheels were manufactured by Flex-King. The weight of the blade-air seeder was 1,360 kg (3,000 lb) or 640 kg/m (375 lb/ft) of blade width, which was well above the 145 kg/m (250 lb/ft) recommended by Charles Fenster (1960) for V-blade penetration.

Scout 66 variety wheat was seeded on October 2, 1984; and September 29, 1985. Seeding rates were targeted at 111 seeds/m^2 (4.5 x 10^5 seed/acre or 30 lb/acre), anticipating a 70% germination and emergence rate to provide about 78 plants/m^2 (3.15 x 10^5 plants/acre). Seeders were calibrated by catching seeds dropped during 30-m (100-ft) runs.

In 1985, cone index measurements were made with a penetrometer as an index of resistance to seeder penetration. The hydraulic powered cone penetrometer, designed and constructed by G. L. Barker, was similar to a unit described by Williford et al. (1972). The penetrometer tip conformed to the ASAE (1983) standard for a 12.83-mm (0.505-in.) diameter cone with a 30-deg tip. Cone penetration rate was adjusted to the recommended 1.83 m/min (72 in./min. Soil density measurements were made in the seed zone beneath the press wheel imprint for each seeder. The density measurements were obtained from soil cores, 6.35 cm (2.54 in.) in length by 3.50 cm (1.38 in.) in diameter. At the same time, seed cover firmness measurements were made with a crust penetrometer having a flat 4.8-mm (0.19-in.) diameter tip.

Seedling counts were made 15 and 30 days after planting. Depth of seed cover was made by grasping the seedling at the point of emergence from the soil and lifting the seedling and attached soil out with a putty knife. The distance from the point of emergence to the seed was then measured. The 1984 to 85 winter wheat crop was harvested for grain yeild with a Hege 125b plot combine on June 17, 1985. The 1985 seeding was evaluated for stand establishment only, and the crop was not carried through to maturity.

RESULTS AND DISCUSSION

Functional Observations

Wheat stubble levels were 2,800 kg/ha (2,500 lb/acre) in 1984 and 3,500 kg/ha (3,100 lb/acre) in 1985, and no residue plugging occurred with the seeders: however, dense soil in wheel tracks required adjustments on two of the drills.

All three seeders operated satisfactorily in the 3,500 kg/ha (3,100 lb/acre) of standing stubble and where the stubble had been sweep-tilled and disked.

The disk drill easily passed through all residue conditions. The double-disk openers required coulters to cut the soil for disk opener penetration on no-till plots and in compacted wheel tracks. Coulters were especially needed where previous harvest and ground sprayer traffic had packed the soil surface. Where sweep tillage had loosened soil beneath the residue, there was some haipinning of straw under coulters; but this did not appear to affect stands. WIth the hoe drill, the 3,500 kg/ha (3,100 lb/acre) of stubble appeared to be near the upper limit that could be handled without plugging.

The blade-air seeder performed better in the firmer surface of no-till or disked treatments than in relatively loose sweep-tilled soil. Of course, sweep-tilling would not be done as a normal field operation immediately before seeding with a blade-air seeder. Some seed scatter occurred as seed was released from the tubes behind the blade. This showed up later with slower emergence or nonemergence of the seed that was not beneath press wheel tracks. Soil passing over the blade was lifted about 10 cm (4 in.) and settled in a fluffed condition. Maximum available spring downforce was necessary for the press wheels to firm the soil in the seed row. The load was about 45 kg (100 lb) on each press wheel. About 75% of the seed remained in a 7-cm (3-in.) band beneath the 10-cm (4-in.) wide press wheels after 7-cm (3-in.) length plastic tubing extensions were added to the tips of the seed blade seed manifold. This change, suggested by Flex-King, permitted more time for soil settling behind the blade to reduce seed scatter. The seeding rate with the blade-air seeder was increased by 25% above the targeted rate of the other seeders to compensate for losses to seed scatter.

Seedling emergence was satisfactory in tractor tracks after seeder adjustment except for the blade-air seeder when soil moisture was relatively high. The wet clay loam soil sometimes formed compacted flat "chunks" in tractor tracks, leaving seed exposed to drying air in the open cracks. The blade-air seeder was less tolerant to a wide range in soil moisture on this soil compared with the other drills. Relatively wet soil did not flow smoothly over the blade; and on dryer soil, there was the hazard of seeds not sprouting in the fluffed soil behind the blade, even though press wheels were used for firming in the seed row.

Reports from users† indicate that the performance of the blade-air seeder is less sensitive to soil water content on medium- and coarse-textured soils than on fine-textured soils. Blade-air seeder user Robert Paris‡ of western Kansas reports that a minimum of 2.5 cm (1 in.) of moist soil is needed above the cutting depth of the blade to assure seedling emergence in a fine-textured Richfield silt loam. Thus, depth of prior blade tillage is restricted to about 7.5 cm (3 in.) in order to reduce seed zone soil drying.

Controlled Tests

Soil Cone Index and Seed Opener Penetration: The comparative soil cone index values to 15 cm (6 in.) deep at seeding time in 1984 are presented in Fig. 5 for both tractor wheel tracks and nontracked check areas. There was no difference in cone index with depth between the disk and sweep-tilled treatments.

Coulters were necessary on the no-till plots, especially in wheel tracks, to cut a slot for the double-disk openers to follow. Without the coulters, the double-disk openers did not penetrate the no-till soil with cone index values in the 1,000- to 1,800-kPa (140- to 270-psi) range. The hoe-press drill also satisfactorily penetrated firm no-till and wheel track surfaces when properly adjusted. The angle of the soil engaging points on the hoe-press drill were adjusted to maintain penetration in dense soil. The weight of the blade-air seeder was sufficient to maintain penetration depth in all conditions tested.

A dense layer (hardpan) occurred at the 10-cm (4-in.) depth under all tillage treatments (Fig. 5). This hard layer apparently was the result of previous repeated sweep tillage operations at the same depth and did not restrict planter performance in the less dense soil above the hard layer except in wheel tracks.

Seed Populations and Emerged Stands: The seed populations were within 90% of the targeted rates in both years (Tables 1 and 2). However, most of the variation was below the targeted level, and the resulting emerged plant populations were lower than targeted. The hoe drill produced the highest seedling emergence percentages in both years, varying between 63 and 72%. This was the result of seed being placed in a narrow trench formed by the point opener and the weighted press wheel firming the soil for good seed-soil contact.

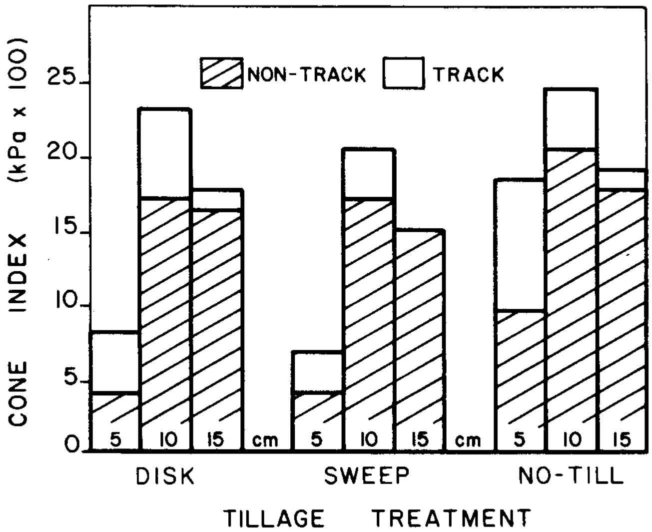


Fig. 5—Soil cone index by depth and tillage treatment as measured by cone penetrometer in and away from tractor tracks, Pullman clay loam, October 2, 1984, Bushland, TX.

†Personal communication, 1983; Jerry Allen, USDA-SCS, Guymon, OK.

‡Personal communication, 1988; Robert Paris, Agricultural Engineer, Dighton, KS.

TABLE 1. SEEDER TEST DATA, SEED AND PLANT POPULATION, EMERGENCE, SEED DEPTH, GRAIN YIELD, SEEDING WHEAT AFTER WHEAT, BUSHLAND, TX, 1984

Tillage treatment	Seeding rate, sd/m^2	Plant population, pl/m^2	Emergence, %	Seed depth: Mean, cm	Seed depth: Standard dev., cm	Grain yield, kg/ha
CLEAN						
Disk drill	107	60	56d*	3.2	0.45	2,630*
Hoe drill	100	70	70a	3.1	0.32	2,610a
Blade-air	139	79	57cd	6.0	0.40	2,430a
SWEEP						
Disk drill	107	62	58cd	3.7	0.51	2,770a
Hoe drill	100	65	64abc	3.5	0.38	2,500a
Blade-air	139	75	54d	6.0	0.67	2,610a
NO-TILL						
Disk drill	107	64	60bcd	3.1	0.47	2,410a
Hoe drill	100	66	66ab	3.5	0.40	2,480a
Blade-air	139	78	56d	5.8	0.62	2,670a

*Column values followed by the same letter are not significantly different at the 5% level, according to Duncan's multiple range test.

TABLE 2. SEEDER TEST DATA, SEED AND PLANT POPULATION, EMERGENCE, SEED DEPTH, SEED-ROW DENSITY, SEEDING WHEAT AFTER WHEAT, BUSHLAND, TX, 1985

Tillage treatment	Seeding rate, sd/m^2	Plant population, pl/m^2	Emergence, %	Seed depth: Mean, cm	Seed depth: Standard dev., cm	Seed row soil density, gm/cc
CLEAN						
Disk drill	98	54	55de*	3.3	0.89	1.14cd*
Hoe drill	115	81	70ab	4.1	0.60	1.26ab
Blade-air	139	78	56cde	7.5	0.41	1.27ab
SWEEP						
Disk drill	98	52	53de	3.3	0.79	1.04d
Hoe drill	115	83	72a	4.5	0.37	1.27ab
Blade-air	139	70	50e	7.7	0.30	1.21abc
NO-TILL						
Disk drill	98	58	59cd	3.5	0.74	1.17bc
Hoe drill	115	72	63bc	4.2	0.54	1.31a
Blade-air	139	82	59cd	7.5	0.32	1.30a

*Column values followed by the same letter are not significantly different at the 5% level, according to Duncan's multiple range test.

However, the higher emergence with the hoe drill was not always statistically significant under sweep-tilled or no-till conditions (Tables 1 and 2). The disk drill and blade-air seeders produced lower seedling emergence percentages, varying between 50 and 60%. The reasons for lower emergence percentages with the blade-air seeder were discussed earlier, and the increased seeding rate adjustment produced stand populations in the targeted range. Although the seeding rate was increased by 25% for the blade-air seeder, emergence data showed that a 15 to 20% increase would be adequate.

There were two apparent reasons for the disk drill having lower emergence percentages than the hoe drill: (a) the seed slot formed by double-disk openers was less well defined than with hoe openers, partially because of the ripple coulter cutting soil ahead of the double-disk opener; and (b) the pair of angled plastic press wheels straddling the seed row did not firm the soil as well above the seed. The net result was poorer seed-soil contact. For seeding wheat under these conditions, a single 5- x 32-cm (2- x 13-in.) press wheel would have been preferable on the disk drill.

Seed Depth: Seed depth, defined as the depth of soil cover over the seed, was not affected by prior tillage. The type of seed placement mechanism did affect seeding depth, and there was minor variation between years with the same seeder.

The seeding depths of the disk and hoe drills were moderate, ranging from 3 to 4.5 cm (1.2 to 1.8 in.) whereas depth was noticeably greater for the blade-air seeder, ranging from 6 to 7.5 cm (2.4 to 3 in.). The reason for deeper seed placement with the blade-air seeder is that the seed is released at the same level as the cutting depth of the blade. In order to allow for minor soil surface irregularities, the relatively wide blade would not operate satisfactorily at less than an average 6-cm

(2.4-in.) depth. Seeding depth for all seeders was usually slightly shallower (1 to 1.5 cm) (0.4 to 0.6 in.) in tractor track depressions. Seed depth measurements, listed in the tables and discussed herein, were measured away from tractor tracks.

The uniformity of seeding depth with each type of seeder was considered very good when the equipment was properly adjusted. The standard deviation was usually less than 0.60 cm (0.24 in.) (Tables 1 and 2). In 1985, the standard deviation for the disk drill increased to the 0.74- to 0.89-cm (0.3- to 0.36-in.) range. The increase is attributed to the coulters being operated deeper than necessary ahead of the double-disk openers. The coulter slot was deeper than the disk opener operating depth, and some seed fell deeper in the slot. In all instances, the standard deviation was less than 1.0 cm (0.4 in.), which was considered acceptable.

Soil Density and Strength in Seed Zone: The density of the soil above the seed was significantly greater for the hoe drill and blade-air seeder than for the disk drill (Table 2). The difference is directly related to force of the weighted press wheels operating directly over the seed row on the hoe drill and blade-air seeder, compared with light press wheels operating on both sides of the seed row on the disk drill.

The soil penetration resistance above the seed, as measured with a crust penetrometer, averaged only 375 kPa (55 psi) for the disk drill, compared with 675 kPa (95 psi) for the hoe drill and blade-air seeder. The average soil density above the seed varied from 1.14 to 1.26 gm/cc (71 to 79 lb/ft^3) for the disk and hoe drills, respectively, after clean tillage. The 80% increase in penetrometer reading, compared with only an 11% increase in bulk density, illustrates that moderate increases in soil density can cause a major increase in soil penetration resistance. The greater soil density measured behind weighted press wheels on this fine-textured soil in the semiarid Southwestern Great Plains is considered a help rather than a hindrance to stand establishment of wheat.

Crop Growth and Yield: There was no statistically significant tillage or seeder effect on grain yield for wheat sown in 1984 and harvested in 1985 (Table 2). Fall tillering and spring growth were such that the resulting plant density on all treatments was adequate for the soil moisture available and the yield level. In years when dry weather may delay seeding and cooler temperatures limit fall growth and tillering, then emergence and stand density become more critical.

CONCLUSIONS

1. All seeders successfully operated through the 3,500 kg/ha (3,100 lb/acre) of dry wheat stubble available in the study. This appeared to be near the upper limit for the hoe-press drill.
2. Seeder adjustment was required to maintain seed opener penetration in wheel tracks and no-till soil surfaces. The seeders tested can be adjusted to penetrate dense soils for satisfactory seed placement.
3. The hoe-press drill produced greater, though not always significant, seedling emergence than either the disk or the blade-air seeder.
4. Loaded press wheels, operating directly over the seed row, significantly increased seed zone soil density and seed-soil contact on the hoe-press drill and blade-air seeders.
5. The blade-air seeder had a minimum functional seeding depth of 6 cm (2.4 in.) that was nearly twice the depth of the other seeders.
6. The blade-air seeder required loaded press wheels to firm the seed zone after blade-action soil fluffing.
7. The blade-air seeder can perform the dual function of subtillage and seeding except when soils are wet and sticky.

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